The NOAA Ship *Okeanos Explorer*

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Animals of the Fire Ice

An essential component of the NOAA Office of Ocean Exploration and Research mission is to enhance understanding of science, technology, engineering, and mathematics used in exploring the ocean, and build interest in careers that support ocean-related work. To help fulfill this mission, the Okeanos Explorer *Education Materials Collection is being developed to encourage educators and students to become personally involved with the voyages and discoveries of the* Okeanos Explorer*—America's first Federal ship dedicated to Ocean Exploration. Leader's Guides for Classroom Explorers focus on three themes: "Why Do We Explore?" (reasons for ocean exploration), "How Do We Explore?" (exploration methods), and "What Do We Expect to Find?" (recent discoveries that give us clues about what we may find in Earth's largely unknown ocean). Each Leader's Guide provides background information, links to resources, and an overview of recommended lesson plans on the Ocean Explorer Web site (*http://oceanexplorer.noaa.gov*). An Initial Inquiry Lesson for each of the three themes leads student inquiries that provide an overview of key topics. A series of lessons for each theme guides student investigations that explore these topics in greater depth. In the future additional guides will be added to the Education Materials Collection to support the involvement of citizen scientists.*

This lesson guides student inquiry into the key topic of Energy within the "Why Do We Explore?" theme.

Focus
Methane hydrate ice worms and hydrate shrimp

Grade Level
5-6 (Life Science)

Focus Question
What factors tend to resist changes in the pH of the ocean, and why is the ocean becoming more acidic?

Learning Objectives

- Students will be able to define and describe methane hydrate ice worms and hydrate shrimp.
- Students will be able to infer how methane hydrate ice worms and hydrate shrimp obtain their food.
- Students will be able to infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

Materials

- Copies of the *Fire Ice Animals Inquiry Guide*, one for each student group
- Copies of the *Methane Hydrate Molecule Construction Guide Student Handout*, one for each student group
- Materials for constructing a methane hydrate molecule model:

  For constructing a pentagon:
  - Paper, unlined 8-1/2" X 11"
  - Pencil
  - Protractor or compass

  For constructing the dodecahedron, clathrate cage, methane molecule and methane hydrate model:
  - Scissors
  - Cardboard or card stock (enough to make 13 pentagons)
  - Ruler, 12-inch
  - 11 - Bamboo skewers, 12" long
  - 20 - Styrofoam balls, 1/2" diameter
  - 4 - Styrofoam balls, 1-1/2" diameter
  - 1 - Styrofoam ball, 1" diameter
  - Tape, wrapping or strapping
  - Spray paint, water-based latex; dark blue, light blue, red, and black
  - Fishing line, 8 lb test; or light colored thread
  - (optional) Materials for constructing posters or three-dimensional models (see Learning Procedure, Step 7)

Audiovisual Materials

- None

Teaching Time

One or two 45-minute class periods plus time for student research

Seating Arrangement

Groups of four to six students

Methane hydrate looks like ice, but as the "ice" melts it releases methane gas which can be a fuel source. Image credit: Gary Klinkhammer, OSU-COAS

Maximum Number of Students

32

Key Words and Concepts

Cold seeps
Methane hydrate
Clathrate
Methanogenic Archaeobacteria
Polychaete
Alvinocarid shrimp
Ice worm
Hydrate shrimp

Background Information

> **For kicks, oceanographer William P. Dillon likes to surprise visitors to his lab by taking ordinary-looking ice balls and setting them on fire. 'They're easy to light. You just put a match to them and they will go,' says Dillon, a researcher with the U.S. Geological Survey (USGS) in Woods Hole, Mass. If the truth be told, this is not typical ice. The prop in Dillon's show is a curious and poorly known structure called methane hydrate.**
>
> from "The Mother Lode of Natural Gas"
> by Rich Monastersky.
> http://journals2.iranscience.net:800/www.sciencenews.org/www.sciencenews.org/Sn_arch/11_9_96/Bob1.htm

Methane hydrate is a type of clathrate, a chemical substance in which the molecules of one material (water, in this case) form an open lattice that encloses molecules of another material (methane) without actually forming chemical bonds between the two materials. Methane is produced in many environments by a group of Archaea known as methanogenic Archaeobacteria. These Archaeobacteria obtain energy by anaerobic metabolism through which they break down the organic material contained in once-living plants and animals. When this process takes place in deep ocean sediments, methane molecules are surrounded by water molecules, and conditions of low temperature and high pressure allow stable ice-like methane hydrates to form. Besides providing entertainment for oceanographers, methane hydrate deposits are significant for several other reasons:

- The U.S. Geological Survey has estimated that on a global scale, methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and

Iceworms (*Hesiocaeca methanicola*) infest a piece of orange methane hydrate at 540 m depth in the Gulf of Mexico. During the Paleocene epoch, lower sea levels could have led to huge releases of methane from frozen hydrates and contributed to global warming. Today, methane hydrates may be growing unstable due to warmer ocean temperatures. Image credit: Ian MacDonald. *http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/iceworms_600.jpg*

conventional natural gas combined.

- Methane hydrates can decompose to release large amounts of methane which is a greenhouse gas that could have (and may already have had) major consequences to the Earth's climate.
- Sudden release of pressurized methane gas may cause submarine landslides which in turn can trigger catastrophic tsunamis.
- Methane hydrates are associated with unusual and possibly unique biological communities containing previously-unknown species that may be sources of beneficial pharmaceutical materials.

The biological communities associated with methane hydrates are chemosynthetic, and include food webs that are based on the energy of chemical compounds (in contrast to photosynthetic communities whose food webs are based on photosynthesis that uses energy from the sun). Ocean Exploration expeditions to the Gulf of Mexico have found methane hydrates in the vicinity of "cold seeps," which are areas where hydrocarbons are seeping onto the ocean floor. In some of these areas, explorers have observed polychaete worms that appeared to be actively sculpting methane hydrate ices, and expeditions to other locations (such as the 2001 Deep East Expedition) observed shrimp that appeared to be feeding directly on methane hydrate ices (visit http://oceanexplorer.noaa.gov/explorations/03mex/welcome.html, http://oceanexplorer.noaa.gov/explorations/02mexico/welcome.html, and http://oceanexplorer. noaa.gov/explorations/deepeast01/deepeast01.html for more information).

What are these "fire ice animals" doing? Are they actually consuming methane hydrate ices for food? Until more detailed studies are done on these animals, we won't know for sure. But we can use what is already known about other shrimps and polychaete worms to infer some possible answers. These inferences can lead to hypotheses about the relationships between the animals and methane hydrate ices, and can form the basis for experiments to find out more about these strange deep-sea animals. In this activity, students will research cold-seep communities and typical feeding habits of polychaetes and shrimp to make inferences about the relationships between fire ice animals and methane hydrates.

Learning Procedure

1. To prepare for this lesson:
   - If you have not previously done so, review introductory

information on the NOAA Ship *Okeanos Explorer* at http://oceanexplorer.noaa.gov/okeanos/welcome.html. You may also want to consider having students complete some or all of the Initial Inquiry Lesson, "To Boldly Go" (http://oceanexplorer.noaa.gov/okeanos/edu/leadersguide/media/09toboldlygo.pdf).

- Visit http://oceanexplorer. noaa.gov/explorations/deepeast01/logs/oct1/oct1.html and http://oceanexplorer.noaa.gov/explorations/03windows/welcome.html for background on the 2001 Ocean Exploration Deep East expedition to the Blake Ridge and the 2003 Windows on the Deep Ocean Exploration expedition.
- Review questions on the *Fire Ice Animals Inquiry Guide*.
- Review procedures on the *Methane Hydrate Molecule Construction Guide (Educator's Version)*, and gather necessary materials. This activity may be done as a cross-curricular mathematics lesson using student-constructed pentagons and dodecahedrons. Correlations with National Math Education Standards and Expectations are provided at the end of the *Educator's Version*. Alternatively, this activity may be done as a briefer demonstration using dodecahedrons constructed by the educator. In either case, you will need to complete Step 2 in advance. If you plan to construct the model as a demonstration, you should also complete Part 1 of the *Student Handout*.

2. If you have not previously done so, briefly introduce the NOAA Ship *Okeanos Explorer*, emphasizing that this is the first Federal vessel specifically dedicated to exploring Earth's largely unknown ocean. Lead a discussion of reasons that ocean exploration is important, which should include further understanding of energy resources in the ocean.

   Lead an introductory discussion about the 2001 Deep East expedition to the Blake Ridge and the 2003 Windows on the Deep expedition. Briefly describe methane hydrates and why these substances are potentially important to human populations. You may also want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold-seep community in the Gulf of Mexico, and http://www.pmel.noaa.gov/vents/ for more information and activities on hydrothermal vent communities.

3. Lead a discussion about recently-discovered deep-sea chemosynthetic communities (hydrothermal vents and cold

seeps). Emphasize the contrast between communities that depend upon chemosynthesis with those dependent upon photosynthesis. You may want to point out that through both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Review the concepts of food chains or webs, emphasizing that the entire chain or web depends upon primary producers at the base of the chain (or web) that are able to create energy-rich food from non-living components in the surrounding environment.

4. Briefly describe methane hydrates. If you will be using student-constructed dodecahedrons for this activity, have students complete Parts 1 and 2 of the *Student Handout*. Alternatively complete Part 2 as a demonstration.

5. Tell students that expeditions to deep-sea communities often discover new and unusual types of living organisms. Two of these organisms are a type of polychaete called an ice worm and a type of crustacean called a hydrate shrimp. Explain that the ice worms make burrows in methane hydrate ices, and that hydrate shrimp have been seen crawling on top of methane hydrate ices, possibly feeding on the ice surface. Explain that scientists are not certain about the relationships between these animals and methane hydrates, nor how the fire ice animals obtain their food. To plan investigations to answer these questions, we need to use existing knowledge about other types of shrimp, polychaetes, and chemosynthetic communities to make hypotheses that are the basis for experiments and observations to learn more about these animals. Provide each group with a copy of the *Fire Ice Animals Inquiry Guide*, and tell students that their assignment is to find out what is known about polychaetes and shrimps in cold-seep communities, how other polychaetes and shrimps obtain their food, and to make hypotheses about the relationships between methane hydrates, ice worms, and hydrate shrimp. Now on with the Inquiry!

6. Have each student group present the results of their inquiry, then lead a discussion of students' hypotheses. Encourage imagination and creativity, but challenge students to explain how their hypotheses are consistent with existing knowledge. Possible relationships could include:
   - Shrimp and/or worms are directly using methane hydrate as a source of food (this is not particularly likely, since other

shrimps and polychaetes are heterotrophic).

- Shrimp and/or worms are consuming methane hydrate which is used by symbiotic chemosynthetic bacteria living inside the animals (this would be analogous to many similar symbioses, and a variety of bacteria have been found to be closely associated with ice worms).
- Shrimp and/or worms are grazing the surface or interior of methane hydrate ices, and are eating chemosynthetic bacteria that use methane hydrate as an energy source (bacterial mats have been found in cold-seep communities, and grazing or deposit-feeding is common among other shrimp and polychaetes).
- Ice shrimp that burrow into methane hydrate ices could be deriving protection from predators (burrowing behavior is typical among many other polychaetes).

Have students discuss what sort of investigations might be undertaken to test their hypotheses.

7. (optional) Have student groups construct a poster or three-dimensional model illustrating their ideas about a methane hydrate community. You may provide materials, or challenge students to find their own, such as colored paper, color markers, modeling clay, glitter (to represent bacteria), Styrofoam pieces (to represent methane hydrates), etc.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then click "Habitats," the "Deep Sea" for links to resources about hydrothermal vents and chemosynthetic communities.

The "Me" Connection

Have students write a short essay on how additional knowledge about "fire ice animals" could be important to their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science, Physical Science

Assessment

Students' responses to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. Follow events aboard the *Okeanos Explorer* at http://oceanexplorer.noaa.gov/okeanos/welcome.html.
2. Review resources and Ocean Energy Overview (Appendix A)

in the Oceans of Energy lesson for additional information and links to activities about energy from the ocean.

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(All of the following Lesson Plans are targeted toward grades 5-6)

A Piece of Cake
(7 pages; 282kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/cake.pdf

Focus: Spatial heterogeneity in deep-water coral communities (Life Science)

Students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deep-water hard bottom communities. Students will also be able to explain how organisms, such as deep-water corals and sponges, add to the variety of habitats in areas such as the Cayman Islands.

Deep Gardens
(11 pages; 331kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/deepgardens.pdf

Focus: Comparison of deep-sea and shallow-water tropical coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts, describe three types of coral associated with deep-sea coral communities, and explain three benefits associated with deep-sea coral communities. Students will explain why many scientists are concerned about the future of deep-sea coral communities.

Let's Make a Tubeworm!
(6 pages, 464k) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/ edu/media/gom_tube_gr56.pdf

Focus: Symbiotic relationships in cold-seep communities (Life Science)

In this activity, students will be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold-seep communities, and list at least five organisms typical of these communities. Students will also be able to define symbiosis, describe two examples of symbiosis in cold-seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

Journey to the Unknown & Why Do We Explore
(10 pages, 596k) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa. gov/explorations/02galapagos/background/education/media/ gal_gr5_6_l1.pdf

Focus: Ocean Exploration (Life Science/Earth Science/Physical Science)

In this activity, students will experience the excitement of discovery and problem-solving to learn about organisms that live in extreme environments in the deep ocean and come to understand the importance of ocean exploration.

Chemists with No Backbones
4 pages, 356k)
(from the 2003 Deep Sea Medicines Expedition)
http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_ChemNoBackbones.pdf

Focus: Benthic invertebrates that produce pharmacologically-active substances (Life Science)

In this activity, students will be able to identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds and will describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases. Students will also be able to infer why sessile marine invertebrates appear to be promising sources of new drugs.

Keep Away
(9 pages, 276k)
(from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20KeepAway.pdf

Focus: Effects of pollution on diversity in benthic communities (Life Science)

In this activity, students will discuss the meaning of biological diversity and compare and contrast the concepts of variety and relative abundance as they relate to biological diversity. Given information on the number of individuals, number of species, and biological diversity at a series of sites, students will make inferences about the possible effects of oil drilling operations on benthic communities.

What's In That Cake?
(9 pages, 276k)
(from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Cake.pdf

Focus: Exploration of deep-sea habitats (Life Science)

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of the Gulf of Mexico. Students will also be able to describe and discuss at least three difficulties involved in studying deep-sea habitats and describe and explain at least three techniques scientists use to sample habitats, such as those found in the Gulf of Mexico.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration Program

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary

of NOAA; nearly 200 pages of lessons focussing on the exploration, understanding, and protection of Earth as a whole system

http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html – Follow Expedition to the Deep Slope 2007 daily as documentaries and discoveries are posted each day for your classroom use.

Van Dover, C.L., et al. 2003. Blake Ridge methane seeps: characterization of a soft-sediment, chemosynthetically-based ecosystem. Deep-Sea Research Part I 50:281–300. (available as a PDF file at http://www.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf)

MacDonald, I. and S. Joye. 1997. Lair of the "Ice Worm." Quarterdeck 5(3); http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html; article on cold-seep communities and ice worms

Siegel, L. J. 2001. Café Methane. http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86; article on cold-seep communities and ice worms from NASA's Astrobiology Institute

http://www.divediscover.whoi.edu/vents/index.html – "Dive and Discover: Hydrothermal Vents;" another great hydrothermal vent site from Woods Hole Oceanographic Institution

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Transfer of energy

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 3.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.

The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education setting.
Please send your comments to: oceanexeducation@noaa.gov

For More Information

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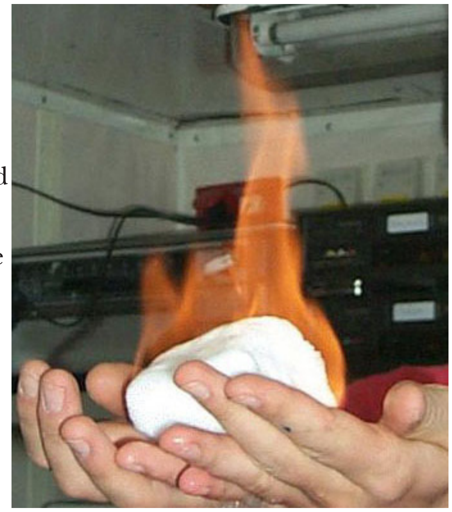
Fire Ice Animals Inquiry Guide

Background Research & Analysis

Expeditions to deep-sea communities often discover new and unusual types of living organisms. Two examples are polychaete worms called ice worms and crustaceans called hydrate shrimp. These animals have been seen on (and in) methane hydrates, which are ice-like substances formed when molecules of frozen water surround molecules of methane gas. If you hold a piece of methane hydrate in your hand, you can set it on fire, so methane hydrates have been nick-named "fire ice."



Methane hydrate looks like ice, but as the "ice" melts it releases methane gas which can be a fuel source. Image credit: Gary Klinkhammer, OSU-COAS

Ice worms make burrows in methane hydrates, and hydrate shrimp have been seen crawling on top of the ice surface, possibly feeding. Scientists are not certain about the relationships between these animals and methane hydrates, nor how the fire ice animals obtain their food. To plan investigations to answer these questions, we need to use existing knowledge about other types of shrimp, polychaetes, and chemosynthetic communities to develop hypotheses that guide experiments and observations to learn more about these animals.

Your assignment is to find out what is known about polychaetes and shrimp in cold-seep communities, how other polychaetes and shrimp obtain their food, and to make hypotheses about the relationships between methane hydrates, ice worms, and hydrate shrimp. You can find information on feeding habits of shrimp and polychaetes in general in encyclopedias and general biology books. Information at http://www.wetwebmedia.com/polychaetes.htm and http://www.wetwebmedia.com/marine/inverts/arthropoda/shrimp/corlband.htm may also be useful, although the emphasis of this site is on aquaria. There is not much information presently available on hydrate shrimp, other than the fact that they have been observed on methane hydrates at the Blake Ridge off the coast of South Carolina. Two good sources of information on ice worms are http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html and http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86. If you do keyword searches to find additional references, you need to know that the name "ice worm" has also been used to describe animals that inhabit glaciers and similar environments, so you should also include "methane" in your search query.

Fire Ice Animals Inquiry Guide - Page 2

When you have completed your research, answer the following questions:

1. What is the basis of food webs in cold-seep communities?

2. What have explorers to cold-seep communities observed about ice worms and hydrate shrimp?

3. How do polychaetes and shrimp, in general, obtain their food?

4. What are the relationships that you hypothesize between ice worms, hydrate shrimp, and methane hydrates?

Methane Hydrate Molecule Construction Guide *(Educator's Version)*

Learning Objectives

- Students will demonstrate geometric properties through hands on manipulation of geometric shapes.
- Students will be able to construct a pentagonal dodecahedron.
- Students will be able to construct a model of a methane hydrate molecule.

Materials

Materials for constructing a methane hydrate molecule model

For constructing a pentagon:

- Paper, unlined 8-1/2" X 11"
- Pencil
- Protractor or compass

For constructing the dodecahedron, clathrate cage, methane molecule and methane hydrate model:

- Scissors
- Cardboard or card stock (enough to make 13 pentagons)
- Ruler, 12-inch
- 11 - Bamboo skewers, 12" long
- 20 - Styrofoam balls, 1/2" diameter
- 4 - Styrofoam balls, 1-1/2" diameter
- 1 - Styrofoam ball, 1" diameter
- Tape, wrapping or strapping
- Spray paint, water-based latex; dark blue, light blue, red, and black
- Fishing line, 8 lb test; or light colored thread

Teaching Time

Three or four 50-minute class periods or may be sent home as an enrichment activity

Definitions

- Polygon – a geometric shape made up of vertices that are connected with line segments
- Vertex – a point where the sides of an angle meet
- Pentagon – a geometric shape with five equal sides and five 108° angles
- Dodecahedron – a three-dimensional geometric shape that has 12 faces (regular pentagons), 20 vertices, and 30 edges

Prerequisite Skills

Students should have basic knowledge of geometric shapes and know how to draw a pentagon. If not, directions for drawing a pentagon using a compass or protractor may be found in middle school math textbooks or in the links below.

Methane Hydrate Molecule Construction Guide *(Educator's Version)* - Page 2

Procedure

1. General Notes:
   - For grade 5-6 students, the educator may want to demonstrate each step of drawing the pentagon as students follow along.
   - Use a good quality latex spray paint; oil-based paints containing organic solvents tend to melt the Styrofoam.
   - When constructing the clathrate cage, the educator should demonstrate each step as students follow along.
   - Be sure the skewers are inserted into the middle of the Styrofoam balls.
2. (Advance Preparation) Spray paint skewers and Styrofoam balls:
   a. Paint ten skewers light blue to represent hydrogen bonds between water molecules
   b. Paint one skewer red to represent the electrostatic bonds in the methane molecule
   c. Paint twenty 1/2" Styrofoam balls dark blue to represent water molecules
   d. Paint one 1" Styrofoam ball black to represent the carbon atom
   e. Note: the 4 1-1/2" Styrofoam balls remain white to represent hydrogen atoms
   f. Cut light blue skewer sticks into thirty 3-3/4" lengths. Cut the red skewer stick into four 2" lengths.
3. Lead an introductory discussion of how mathematical models help us understand science concepts.
4. Tell students that they will be using concepts and skills they have learned in the math class to build a pentagonal dodecahedron, a clathrate cage, and methane hydrate model.
5. Give each student group a copy of the *Methane Molecule Construction Student Handout*. Have each group complete Part 1.
6. Have each group complete Part 2, or do this part as a demonstration.
7. Count the vertices, edges, and faces of the completed dodecahedron. Discuss the symmetry of the dodecahedron.

Be sure students understand that each of the dark blue Styrofoam balls represents a water molecule consisting of two hydrogen atoms and one oxygen atom. To keep the model simple, we don't show all of these atoms separately.

Resources

http://wiki.answers.com/Q/How_would_you_draw_a_regular_pentagon
http://www.barryscientific.com/lessons/polygon.html

Methane Hydrate Molecule Construction Guide *(Educator's Version)* - Page 3

National Math Education Standards and Expectations

Analyze characteristics and properties of two-and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships

In grades 3-5 students should-

- Identify, compare, and analyze attributes of two- and three-dimensional shapes and develop vocabulary to describe the attributes;
- Classify two- and three-dimensional shapes according to their properties and develop definitions of classes of shapes such as triangles and pyramids.

In grades 6-8 all students should-

- Precisely describe, classify, and understand relationships among types of two-and three-dimensional objects using their defining properties;
- Understand relationships among the angles, side lengths, perimeters, areas, and volumes of similar objects.

In grades 9-12 all students should-

- Analyze properties and determine attributes of two- and three-dimensional objects;
- Explore relationships (including congruence and similarity) among classes of two- and three-dimensional geometric objects, make and test conjectures about them, and solve problems involving them.

Use visualization, spatial reason, and geometric modeling to solve problems

In grades 3-5 all students should-

- Build and draw geometric objects;
- Identify and build a three-dimensional object from two-dimensional representation of that object;
- Recognize geometric ideas and relationships and apply them to other disciplines and to problems that arise in the classroom or in everyday life.

In grades 6-8 all students should-

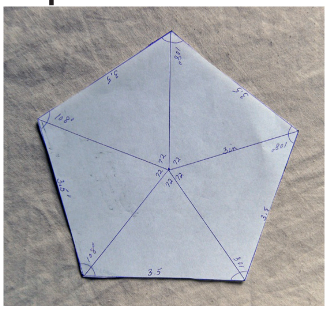
- Draw geometric objects with specified properties, such as side lengths or angle measures;
- Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life.

In grades 9-12 all students should-

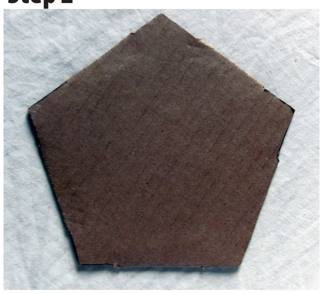
- Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools;
- Use geometric models to gain insights into, and answer questions in, other areas of mathematics;
- Use geometric ides to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture.

Methane Hydrate Molecule Construction Guide Student Handout

Step 1



Step 2



Step 3

Part 1 – Build a pentagonal dodecahedron

1. Draw a pentagon on paper and cut it out. Each side of the pentagon should be four inches long.

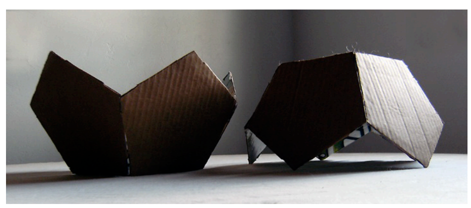
2. Trace the paper pentagon onto cardboard or card stock and cut in out. Your group will need 13 pentagons.

3. Lay one pentagon on a flat surface and surround it with five more pentagons matched side to side. Tape the five outside pentagons to the center pentagon.

4. Carefully pull up one pair of pentagons and tape their common sides together. Repeat until the five pentagons have been taped together, forming a five-sided bowl. This is the bottom half of the pentagonal dodecahedron.

5. Repeat Steps 3 and 4 to make the top half of the pentagonal dodecahedron. The two halves are identical. Place the top half over the bottom half to form the pentagonal dodecahedron. Do not tape the bottom to the top.

Step 5

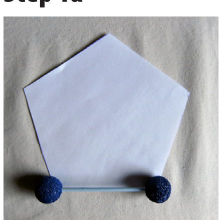


Part 2 – Build the Model Molecules

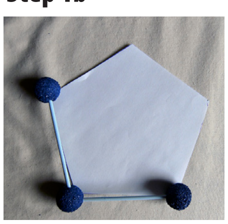
Build the clathrate cage:

1. Place the 13th pentagon on a flat surface. Place a blue stick on one side and two blue balls at each end. Carefully insert the end of the blue stick into the middle of each ball. Repeat with three more balls and four more sticks to form a ball-and-stick pentagon.

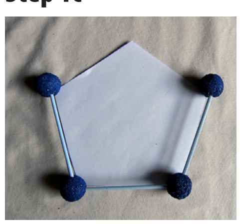
Step 1a



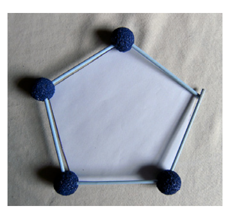
Step 1b



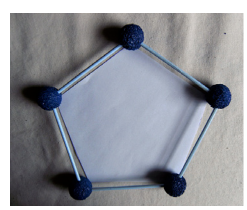
Step 1c



Step 1d

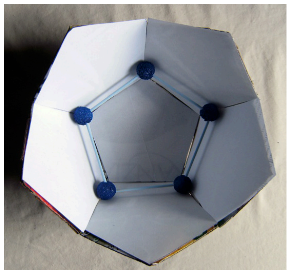


Step 1e



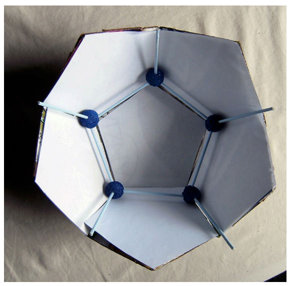
Methane Hydrate Molecule Construction Guide Student Handout– Page 2

Step 2



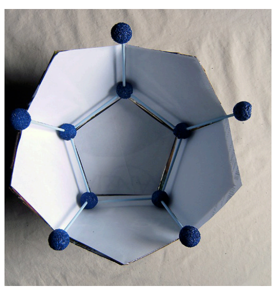
2. Place the ball-and-stick pentagon in one of the dodecahedron halves – be careful, it will lay approximately an inch up from the bottom. The dodecahedron half (bowl) is used as a template to build the ball and stick dodecahedron with the correct stick angle.

Step 3



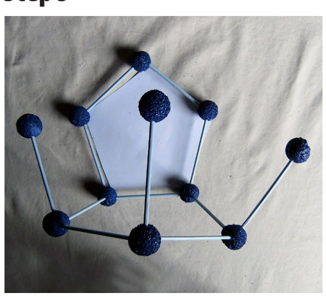
3. Place five light blue sticks inside the center of each of the dark blue balls using the dodecahedron half as a guide for the correct stick angle. It's very important to insert the sticks into the center of the ball at the same angle as the side of the dodecahedron half.

Step 4



4. Insert a dark blue ball on top of each light blue stick. Carefully remove the incomplete cage from the dodecahedron and place it on a flat surface.

Step 5



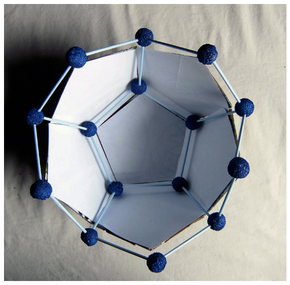
5. Use the 13th pentagon to complete the bottom half of the cage. Turn the ball-and-stick model onto one side and, using the pentagon to determine the correct angle, insert a light blue stick into the center of the two dark blue balls. Then, attach another dark blue ball to connect the two light blue sticks you've just attached. This makes the second face and second pentagon of the cage. The first face was the bottom.

6. Repeat Step 5 four more times to form the remaining faces for the bottom half of the cage.

7. Repeat Steps 1, 2, and 3 to construct the top half of the cage.

Methane Hydrate Molecule Construction Guide Student Handout - Page 3

Step 8



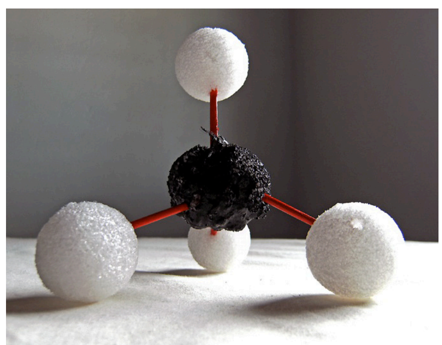
8. Carefully place the bottom half of the cage into the bottom of the cardboard dodecahedron.

9. Attach the two halves of the cage together: Working together with your partners, hold the top half of the cage over the bottom half. The two halves will only fit together one way. Rotate the top half until all of the unattached sticks line-up with a ball. Insert each light blue stick into the center of the corresponding dark blue ball.

Build the Methane Molecule:

10. Insert four red sticks into the black Styrofoam ball so that they are evenly spaced (when the model is placed on a flat surface, three of the sticks and the black ball should look like a tripod with the fourth stick pointing straight up. Attach a white Styrofoam ball to the other end of each of the red sticks.

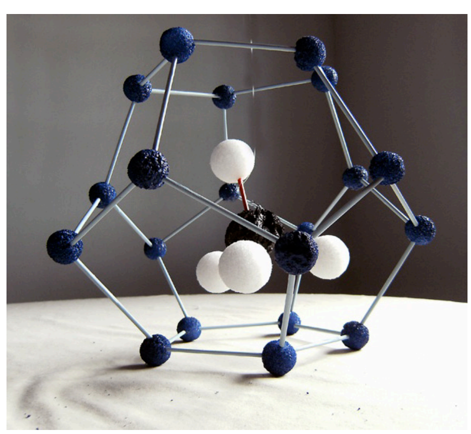
Step 10



Assemble the Methane Hydrate Molecule Model:

11. Suspend the methane molecule model in the middle of the clathrate cage by attaching fishing line from one of its electrostatic bonds (red sticks) to two opposing hydrostatic bonds (light blue sticks) at the top of the cage. Your Methane Hydrate Molecule Model is finished!

Step 11



All photographs by Mellie Lewis, Teacher Facilitator, The College of Exploration.